Spatiotemporal Optimization of a 1 Million Node Network

Over 4 variables

latency, throughput, processing delay, and reliability

Innovations

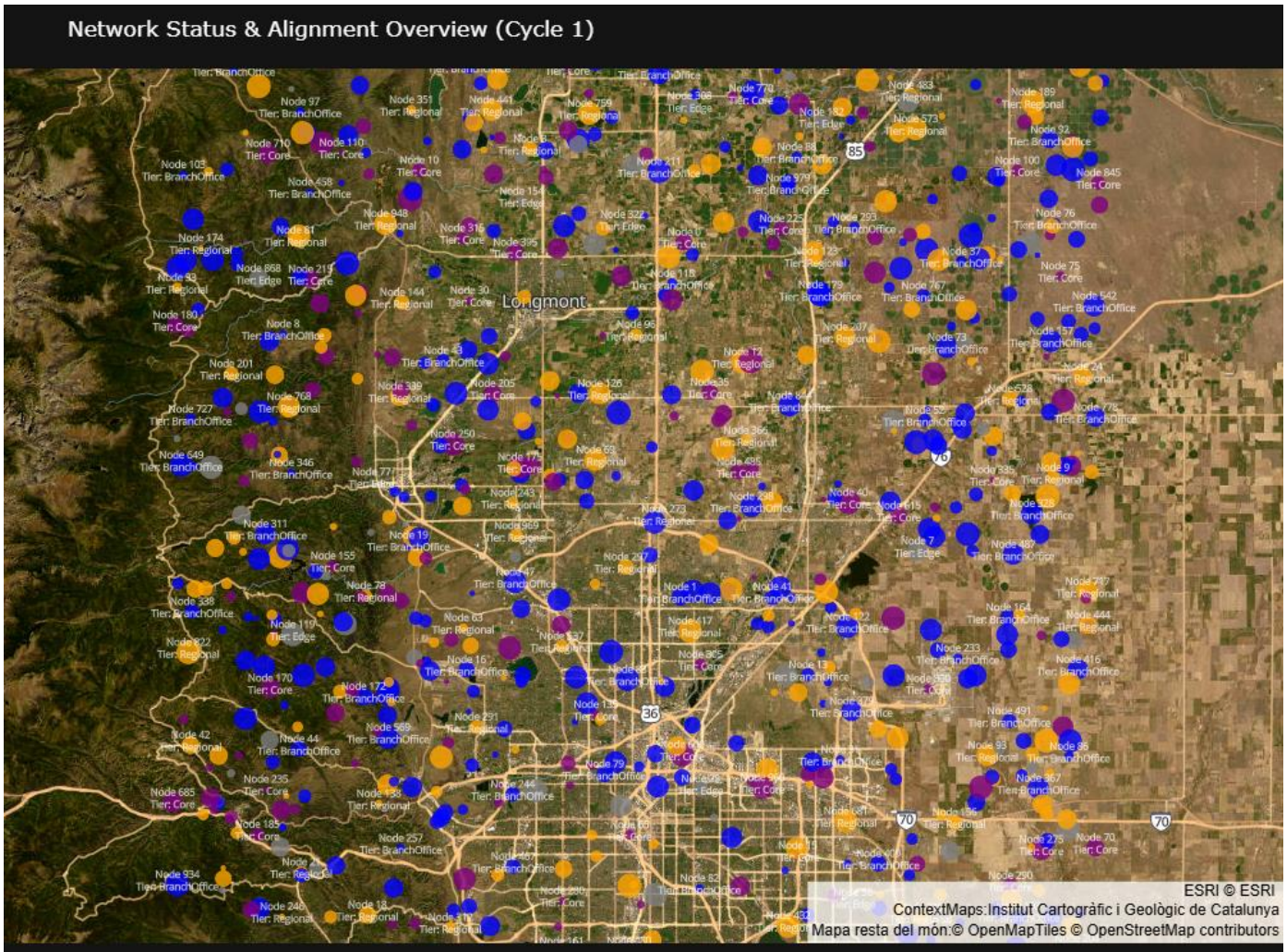
1) Short optimization time

Only **2 cycles** to within **99.9%** of perfect scores on each variable

2) Speed on CPU

Including I/O: **2 minutes**. Measure only: **0.28 seconds**.

Initial Network Status – showing the first 1000 of 1M nodes



Node ID	Tier	T0_Latency	T1_Throughput	T2_ProcessingD	T3_Reliability	Global Sim	Local Sim	Global 7D DP	Local 7D DP
Node 0	Core	10.0	99588.2	2.3	999.5	0.98	0.59	3.92	-0.25
Node 1	BranchOffice	10.0	98752.6	4.0	1000.0	0.98	0.62	3.92	-0.40
Node 2	BranchOffice	33.5	98073.9	15.7	996.0	0.98	0.63	3.81	-0.44
Node 3	Regional	10.0	98259.3	9.0	995.2	0.98	0.61	3.89	-0.31
Node 4	BranchOffice	22.0	100000.0	1.0	990.1	0.99	0.62	3.89	-0.40
Node 5	Core	10.0	100000.0	1.1	996.1	0.99	0.59	3.92	-0.24
Node 6	Regional	10.0	99193.5	3.9	990.7	0.99	0.61	3.90	-0.29
Node 7	Edge	10.0	100000.0	5.5	998.6	0.98	0.63	3.91	-0.40
Node 8	BranchOffice	10.0	100000.0	3.3	996.8	0.99	0.62	3.91	-0.40
Node 9	Regional	19.5	99208.4	1.0	1000.0	0.98	0.61	3.91	-0.31
Node 10	Core	10.0	100000.0	5.6	1000.0	0.98	0.59	3.91	-0.26
Node 11	BranchOffice	10.0	99294.0	9.4	1000.0	0.98	0.62	3.90	-0.41
Node 12	Regional	16.3	99618.9	13.0	996.1	0.98	0.61	3.86	-0.33
Node 13	BranchOffice	10.0	100000.0	3.3	998.1	0.99	0.62	3.92	-0.40
Node 14	Edge	21.6	100000.0	1.0	1000.0	0.98	0.63	3.91	-0.41
Node 15	Core	10.0	100000.0	7.0	1000.0	0.98	0.59	3.90	-0.27
Node 16	BranchOffice	10.0	100000.0	5.6	996.2	0.99	0.62	3.90	-0.40
Node 17	BranchOffice	21.1	100000.0	1.0	998.1	0.98	0.62	3.90	-0.41
Node 18	Regional	10.0	100000.0	1.0	994.5	0.99	0.61	3.92	-0.29
Node 19	BranchOffice	10.0	98866.0	4.5	1000.0	0.98	0.62	3.91	-0.41
Node 20	Core	10.0	100000.0	2.2	1000.0	0.98	0.59	3.92	-0.25

From Initial to Final Network Status

1M nodes optimized in only 2 cycles, requiring 2m 2.1s on CPU

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✓ 2m 2.1s

--- Starting Global Network Optimization Simulation ---

--- Generating and Initializing Static Spatial Data for 1000000 nodes ---
Static spatial data generated and assigned to STATIC_SPATIAL_DATA_RAW.
Created dummy CSV: dummy_network_data.csv with 1000000 rows.
Static spatial data (raw, normalized, blended, centroid) initialized.
Global initial spatial centroid set to: [-0.58333392  0.44444505 -0.29998307]

--- Initializing Network Node DataFrame ---
Network Node DataFrame initialized with 1000000 nodes.

--- Running Initial Optimization Cycle (Cycle 1) for Baseline Metrics ---

--- Starting Network Upgrade Prioritization Cycle 1 (Optimizing by: 7D Dot Product) ---
Updated 1000000 nodes' temporal data for cycle 1.
DEBUG: Current TOTAL_CONVENTIONAL_ALIGNMENT_RUNTIME_US: 282187.40 microseconds
DEBUG: Current TOTAL_7D_METRIC_DOT_PRODUCT_RUNTIME_US: 139061.60 microseconds

--- Upgrade Prioritization for this Cycle ---
  No critical underperformers identified based on 7D Dot Product threshold (-0.5).
  High-Value Global Improvement Candidates (1000000 nodes) based on 7D Dot Product:
    - Node 666944 (Tier: BranchOffice): Global 7D Metric Dot Product=3.9285, Local 7D Metric Dot Product=-0.4000
    - Node 21 (Tier: Regional): Global 7D Metric Dot Product=3.9285, Local 7D Metric Dot Product=-0.3000
    - Node 666902 (Tier: BranchOffice): Global 7D Metric Dot Product=3.9285, Local 7D Metric Dot Product=-0.4000
    - Node 666864 (Tier: Regional): Global 7D Metric Dot Product=3.9285, Local 7D Metric Dot Product=-0.3000
    - Node 666979 (Tier: BranchOffice): Global 7D Metric Dot Product=3.9285, Local 7D Metric Dot Product=-0.4000
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--- Stagnation Detected by New Criteria! ---
  100% of nodes have achieved a score >= 0.9990.
  Current Overall Metric Max: 3.3104
  Optimization for '7D Dot Product' is considered complete.

--- Simulation Finished after 2 cycles ---
Final Global Conventional Temporal Similarity to Perfect: 0.5900

Total Conventional Alignment Runtime: 569772.40 microseconds
Total 7D Metric Dot Product Runtime: 282353.80 microseconds

--- Final Optimized Network Data (First 20 Rows) ---
    T0_Latency  T1_Throughput  T2_ProcessingDelay  T3_Reliability   Longitude   Latitude    Elevation
0    10.000000  100000.000000            1.000000     1000.000000 -104.951186  40.215189  1801.381688
1    10.000000   99184.283390            1.075081      996.786402 -104.955117  39.923655  1822.947057
2    10.000000  100000.000000            1.030892     1000.000000 -105.062413  40.391773  1981.831380
3    20.509439   99107.201684            1.000000      993.036071 -105.116558  40.291725  1764.447460
4    18.799476  100000.000000            1.000000      997.160437 -104.931955  40.425597  1535.518029
5    10.270646   99627.268583            1.000000     1000.000000 -105.412871  39.520218  1916.309923
6    10.000000  100000.000000            2.315632     1000.000000 -104.721843  40.370012  1989.309171
7    19.100960   99935.894524            1.000000     1000.000000 -104.700841  39.961479  1890.264588
8    10.000000  100000.000000            2.243083      998.876379 -105.381726  40.139921  1571.676644
9    10.112279   99583.771550            4.601453     1000.000000 -104.555331  40.021848  1707.330970
10   11.628569  100000.000000            1.000000     1000.000000 -105.235444  40.274234  1728.075166
11   13.924133  100000.000000            7.952660     1000.000000 -104.931566  39.518790  1808.817749
12   10.000000   99272.491614            1.000000      999.386916 -104.887904  40.116934  1971.874039
13   10.000000  100000.000000            1.000000      994.821121 -104.818180  39.859508  1718.515977
14   10.000000  100000.000000            1.000000     1000.000000 -104.802369  39.560225  1833.383358
15   12.361868   98269.608586            3.018523      995.703341 -104.829362  39.710383  1564.463149
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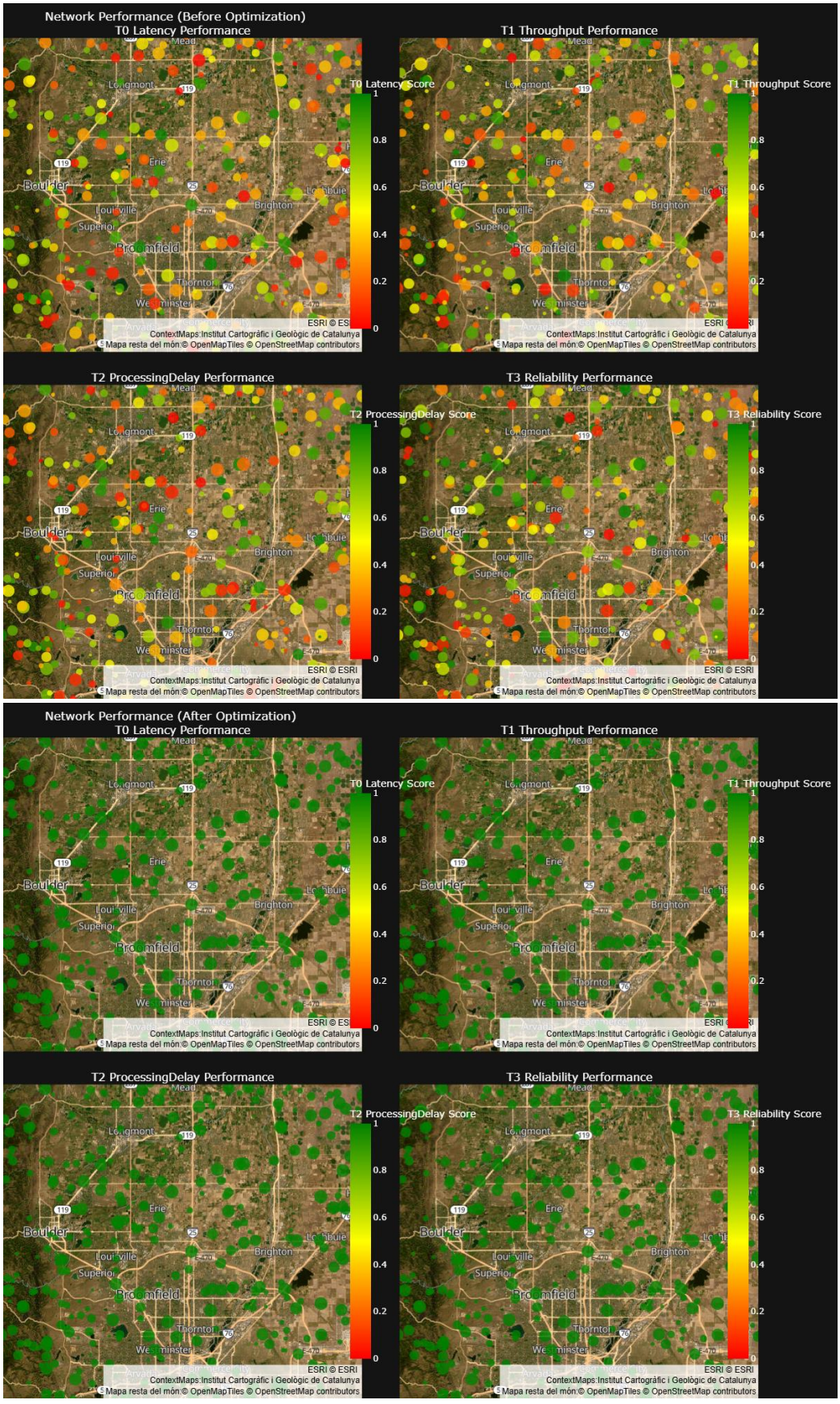
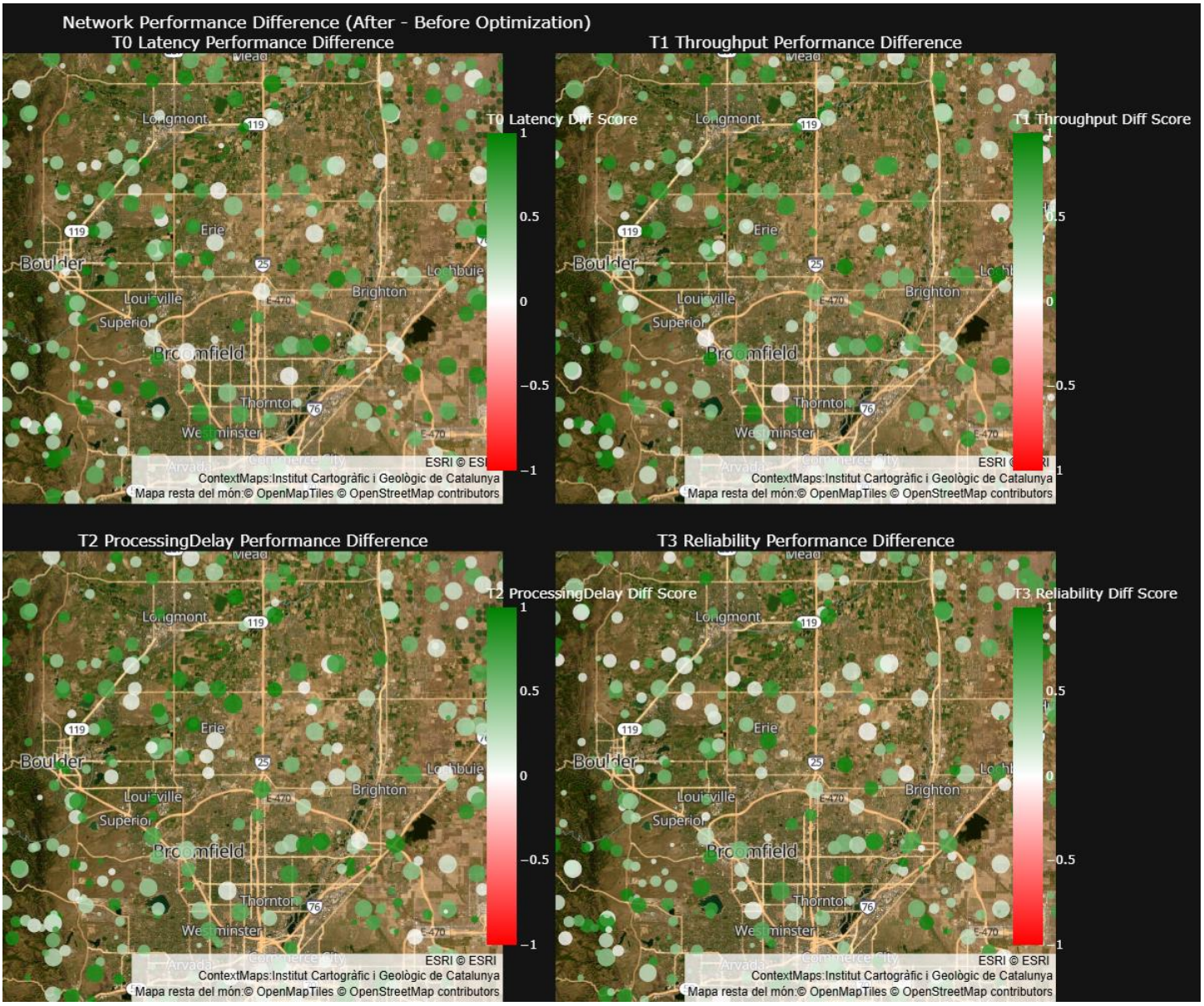
Before vs. After – deepest green indicates best scores

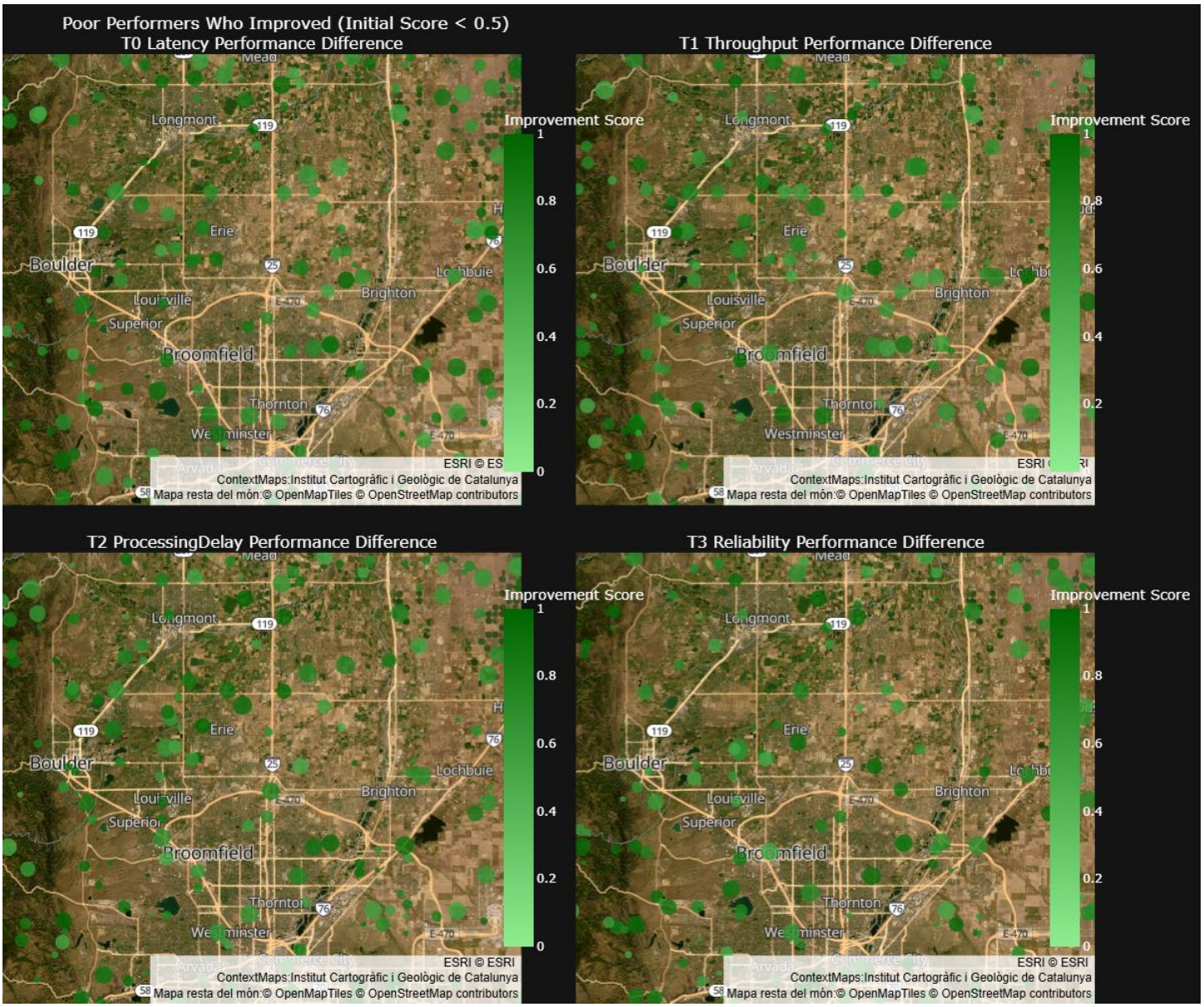


Changes from Optimizations

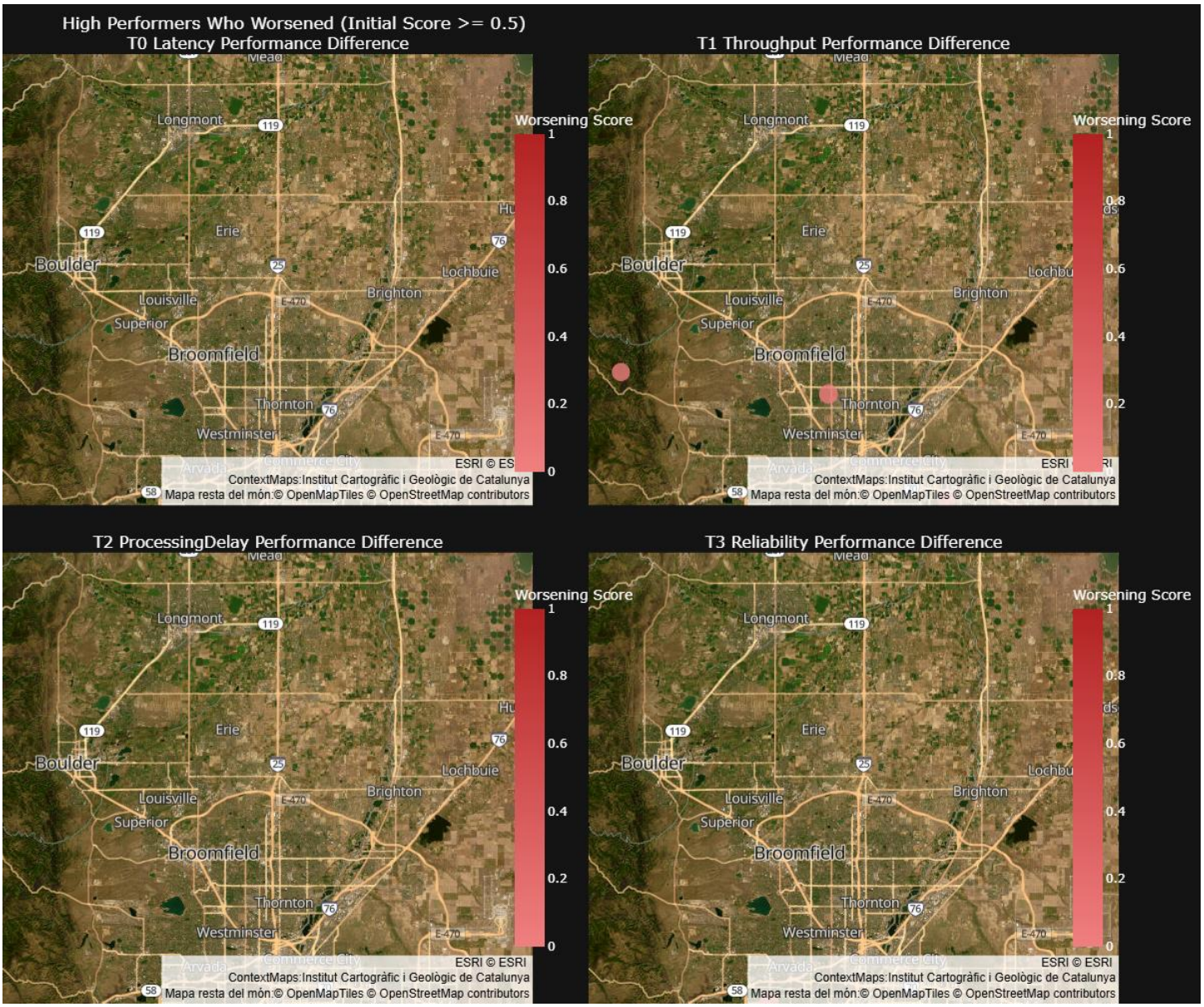
Green = improvements, **white** = no changes; **red** = declines



Improvements



Declines


High Performers Who Worsened (Initial Score >= 0.5)
T0 Latency Performance Difference
T1 Throughput Performance Difference
T2 ProcessingDelay Performance Difference
T3 Reliability Performance Difference
Worsening Score
1
0.8
0.6
0.4
0.2
0
Longmont
Erie
Boulder
Louisville
Superior
Broomfield
Brighton
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